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Method and apparatus for detecting x-rays and use of such apparatus

Technical field

The present invention relates to a method for detecting x-rays as described in the preamble of claim 1. The invention also relates to an apparatus as described in the preamble of claim 4 and a use of such apparatus as described in the preamble of claim 13.

Background to the invention

In medical x-ray imaging the central problem is to achieve the best possible image at the lowest possible radiation dose. To achieve this, high detection efficiency for all x-ray photons passing through the patient is crucial. Current x-ray imaging systems work with Detection Quantum Efficiencies (DQE) ranging from 10% to around 60%.

Silicon is in many ways the ideal detector material. The main advantages are the high quality and purity of the crystal combined with very low cost as a result of research and development in the semiconductor industry and the large volumes of silicon used in this field.

The main disadvantage with silicon is its low atomic number and corresponding decrease in stopping power for higher energy x-rays. A silicon detector wafer can only be made with a maximum thickness of around 1mm, and the standard thickness is about half of that. Thicker detectors will need application of prohibitively high voltages to deplete the whole detector volume to become an efficient x-ray detector. If the x-rays are incident at right angle to the surface this correspond to an efficiency of only 25% at 20keV.

A way around this problem is to orient the detector edge-on to the incident beam. In this geometry, the thickness of the silicon stopping the x-rays could be large enough to stop virtually all incident x-rays. This method is outlined in the invention described in US patent 4,937,453 by Robert S. Nelson. Edge-on detectors for increased efficiency is also conceivable for other semiconductor detectors but is particular important in the case of silicon because of the limited stopping power for this material due to its lightness.

A problem not anticipated in the method and device described in Nelson's patent (US 4,937,453) is that the semiconductor detector is always mechanically damaged in a zone close to the edge when it is cut. The cutting is usually performed with a diamond saw or a laser. In this area a large amount of background current is generated and the active sensors in the semiconductor wafer has to be put some distance from the edge in order not to be saturated by this background current, which would mask the signal from the x-rays. Usually, but not always, one or several guard-rings are placed between the active sensors and the edge to sink the current generated at the edge of the detector and thus preventing it from reaching the active sensors. The distance between the edge and the active sensors are from 0.1mm to 0.6mm and the x-rays stopping in this region will not be detected. This, so called dead area, is equivalent to an inefficiency of the order of 20% in diagnostic x-ray imaging, such as mammography.

The loss of information is even more serious since predominantly the low energy photons that carry the most contrast information to the image will stop in the region close to the edge, which is not an active detector volume, and mainly the high energy photons, with less contrast information, will penetrate further down into the detector.

Summary of the invention

The object with the present invention is to provide a method for detecting x-rays which solves the above mentioned problems by providing a method according to claim 1.

Another object of the invention is to provide an apparatus for detecting x-rays according to claim 4 and a use of said apparatus according to claim 13.

An advantage with the present invention is that it enables a DQE close to 100% for energies of interest in diagnostic x-ray imaging ranging from 10keV to 40keV, combined with a high spatial resolution.

Another advantage is that the present invention is very simple and inexpensive to implement in a detector.

Another advantage is that the detector depth can be made large without having the x-rays passing the dead area close to the edge.

Another advantage is that the present invention improve the x-ray image and/or lower the radiation dose for the patient.

Brief description of drawings

Fig.1 shows the detector chip in perspective looking from the top. A guard ring is indicated together with the strips for the top contact for the individual diodes. The bond pads for each strip for connections to electronics are not indicated.

Fig. 2 shows the detector looking from the side together with incoming x-rays and a collimator defining the shape of the x-ray beam.

Detailed description of the preferred embodiments

A silicon detector is fabricated from a raw silicon wafer that is exposed to different treatments to get the desired resistivity and other material parameters and the pattern of silicon strip sensors defining the individual pixels in the detector is fabricated through standard photolithographic techniques.

In Fig. 1 a detector chip 101 is displayed in a perspective view and a guard ring 102 is indicated together with individual pixel sensors 103 on a front side of the detector. The size of the pixel sensors is mainly determined by the demands on spatial resolution for a certain imaging task. In applications like mammography the distance between two adjacent pixels should be of the order 25μm to 100μm. The dead area 104 corresponds approximately to the distance from the edge of the detector to somewhere in between where the guard ring and where the strips start. The thickness of the wafers normally range from 300μm to 500μm. To deplete the whole volume of the detector a bias voltage is applied between the back of the detector 105, that is usually entirely covered with aluminium. The depletion can for example be achieved with +80V connected to the backside of the detector wafer. The pixel sensors can then be at ground and connected to electronics. In this case the holes created by the incident x-rays are collected by the electronics. With an inverse diode structure for the sensor pixels and -80V connected to the back of the detector the electrons would be collected by the electronics and this would work equally well. The bias voltage necessary to deplete the whole wafer is very dependent on the individual detector type and thickness and ranges from 10V to over 1000V.

The electronics, usually in terms of Application Specific Integrated Circuits, to collect and process the signals from the individual sensor pixels will be connected to the individual sensor pixels through standard interconnection techniques like wire bonding or bump bonding. The pads usually necessary for these interconnections are not indicated in Fig. 1 but should be situated close to the end 106 of the strips.

This invention suggest a geometry between the incident x-rays and the detector such that the inefficiency mentioned above disappears. Fig. 2 shows a detector that is slightly tilted with respect to the incident x-rays in order to make them hitting the detector at a small angle to the detector surface.

To achieve maximum detection efficiency, e.g. for mammography, the detector should be oriented relative to the incident x-rays according to Fig. 2. with a certain angle 107 between the detector surface and the x-rays. The collimator 108 will shape the x-ray beam to match the detector area. By changing the angle of the incident x-rays relative to the surface of the detector the thickness of silicon that the x-ray will encounter is determined. The detection efficiency in turn is determined by the thickness of the silicon and the detection efficiency can thus be selected to meet requirements for a particular imaging task. If we assume a wafer thickness of 0.3mm and an x-ray energy of 25keV that is typical for mammography we will, with an angle of 2.8 degrees, achieve a detection efficiency in silicon exceeding 90 %. In this case, if the collimator slot 109 defining the shape of the incident x-rays has a width of 50µm this would require an overall length of the detector of around 10mm. The incident x-rays will encounter around 7.5mm of silicon. A larger angle would mean slightly decreased detection efficiency but a shorter detector.

For a 0.5mm detector thickness the same performance will be achieved with a slightly larger angle, around 3.8 degrees. Also fairly large angles of around 10 degrees results in as much as around 3mm depth of silicon for any incident x-rays in this case. This yields an efficiency that is high enough for several applications at lower energies, for 20 keV it would exceed 85%.

If the collimator is wider, e.g. 100μm, the detector will have to be made longer in order to cover all the area under the collimator slot 109.

There is a choice weather to have the front side of the detector 101 in Fig. 1 or the back side of the detector 105 in Fig. 1 to face the incoming x-rays. Any of those schemes would work quite well but it is slightly advantageous to have the backside of the detector facing the x-rays. The reason for this is that the depletion zone, i.e. the active detector volume, does not extend all the way to the edge of the detector also in this direction, even if the dead area is much smaller, approximately of the order 1μm, compared to the edge-on case. Since the extension of this dead area is less thick on the back side since less processing of the detector has taken place here it is advantageous to have the x-rays incident to the back side of the detector since this would yield a slightly increased efficiency.

In a system the x-ray imaging object will be placed between two collimator slots which are aligned with respect to each other and look more or less identical. The first collimator will shape the x-ray beam to match the active detector area. The second collimator slot will remove Compton scattered x-rays and the detector will be positioned after this collimator slot.

One important extension of the scheme above is to put several collimator slots and corresponding detectors after each other. This would increase image acquisition time since the area where x-rays are detected is increased. In Fig. 2 this would correspond to putting similar detectors and slots to the left and/or right of the indicated slot and detector. It may also be advisable to put an x-ray absorbing metal plate in between different detectors in this scheme to prevent scattered x-rays to reach adjacent detectors.

Other semiconductors than silicon, such as e.g. Gallium Arsenide or CdZnTe could be used in the scheme above instead of Silicon. They are however more expensive and difficult to work with and parameters like charge collection efficiency for the charge induced by the x-rays are not as good as for Silicon.

Claims

1. A method for detecting x-rays for obtaining improved radiographic images including a step of orienting a semiconductor radiation detector (101) whose height is greater than its thickness, **characterised by** said orienting step comprises a selection of an acute angle (107) between a direction of incident radiation and a side of said detector having said height such that said incident radiation (110) mainly hit the side (100; 105) of said radiation detector (101) and that substantially all of the energy of the radiation is dissipated within the detector.

2. A method according to claim 1 **characterised by** said angle (107) is selected to be less than 10 degrees.

3. A method according to claim 1 or 2 **characterised by** said method further comprises the step of collimating using a collimator (108) with a collimator slot (109) to prevent the incident radiation (110) to hit the edge the detector (101).

4. An apparatus for detection of incident radiation for radiographic imaging comprising:

- x-ray detector means (101) comprising a plurality of semiconductor x-ray strip detectors(103), said detector means being of sufficient height to cause the dissipation of substantially all of the incident radiation within said detector means,
- electrical outputs for each of the strip detectors, and
- electrical connections between each of the semiconductor x-ray strip detectors such that the output corresponding to corresponding points in each of the detectors is combined,

characterised in that said x-ray detector means (101) is oriented relative to the incident radiation (110) such that an acute angle (107) is selected between a direction of said incident radiation and a side of said detector having said height such that said incident radiation mainly hit the side (100; 105) of said detector means (101) and that substantially all of the energy from the incident radiation is dissipated within the detector.

5. An apparatus according to claim 4, **characterised in that** said detector means have a guard ring (102) to sink leak current.

6. An apparatus according to claim 4 or 5, **characterised in that** said thickness of the detector means is between 0.1mm and 1.0mm.

7. An apparatus according to any of claims 4-6, **characterised in that** said apparatus further comprises a collimator (108) with a collimator slot (109) to prevent the incident radiation (110) to hit the edge the detector (101).

8. An apparatus according to claim 7, **characterised in that** said apparatus comprises several detector means, each having a collimator slot (109), placed side by side.

9. An apparatus according to claim 8, **characterised in that** an absorber is placed between said detector means (101) to prevent scatter from one detector means to another.

10. An apparatus according to any of claims 4-9, **characterised in that** said detector means are made of silicon.

11. An apparatus according to any of claims 4-9, **characterised in that** said detector means are made of Gallium Arsenide or CdZnTe.

12. An apparatus according to any of claims 4-11, **characterised in that** said angle (107) is less than 10 degrees.

13. An apparatus according to any of claims 4-12, **characterised in that** said incident radiation (110) hits the backside (105) of the detector means (101).

14. Use of an apparatus for detection of incident radiation in scanned-slot medical imaging, **characterised by** using an apparatus according to any of claims 7-13.

15. Use of an apparatus for detection of incident radiation in scanned-slot medical imaging according to claim 14, **characterised by** said medical imaging is used in mammography, bone densitometry or non-destructive testing.

Abstract

The present invention relates to a method for obtaining improved radiographic images consisting of orienting a semiconductor radiation detector (101) whose height is greater that its thickness, where said orienting step comprises a selection of an acute angle (107) between a direction of incident radiation and a side of said detector having said height such that said incident radiation (110) mainly hit the side (100; 105), preferable the backside, of said radiation detector (101) and that substantially all of the energy of the radiation is dissipated within the detector. The invention also relates to an apparatus implementing said method and a use of such apparatus in scanned-slot medical imaging.

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Fig 1.

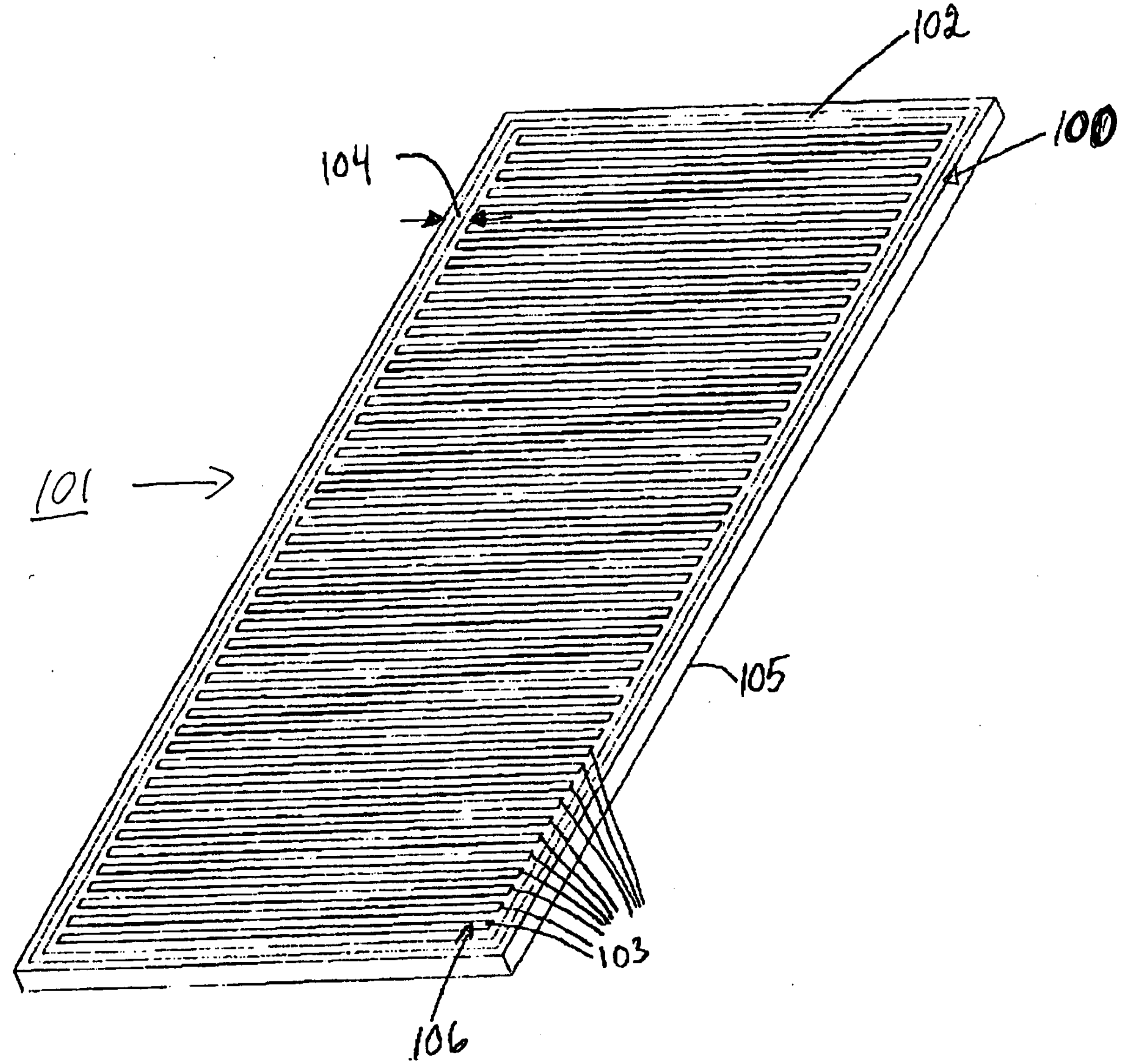
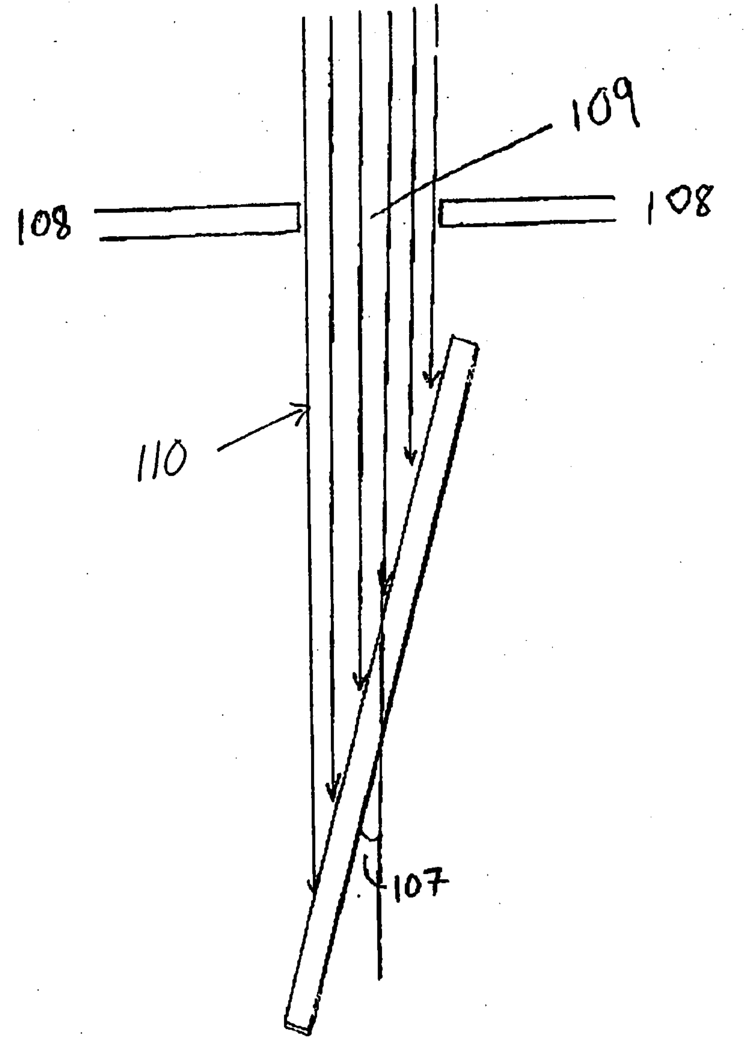


Fig 2.



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